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Comparative analysis of spherical focusing transducers from dense and porous piezoceramic materials

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This paper considers a finite element investigation of ultrasonic spherical transducers made of dense or porous piezoceramic materials polarized in the thickness. By virtue of the axial symmetry of piezoelectric transducers we examined the axisymmetric problems in the plane of the meridian section. Considered transducer includes spherical segment, radial surface of which was covered by the electrodes. For effectiveness of acoustic wave excitation, due to the large difference between impedance of piezoelectric ceramics and impedance of surrounding acoustic medium, one or two elastic matching layers with successively decreasing impedances were added to the active element of transducer.

In the case of porous piezoceramics in order to determine its effective moduli, a comprehensive approach was used, which includes the effective moduli method, the modeling of special porous structures of representative volumes, and the finite element method. This technology has been realized in the finite element packages ANSYS and ACELAN-COMPOS.

For considered transducers in the finite element package ANSYS the regular grid of quadrilateral bilinear elements were built, where each piezoelectric element had its elemental coordinate system with the axis of ordinates is directed along the radial direction. Irregular grid of acoustic finite elements with impedance conditions on the external boundary of acoustic region has been formed in the area, surrounding transducer.

In the first stage, modal and harmonic analyses for piezoelectric transducers without acoustic medium were carried out. Further for the considered transducers the coupled harmonic problem of electroelasticity and acoustics has been solved in ANSYS for the main resonance frequency of thickness mode and the characteristics of the focal spot in the acoustic medium have been identified.

The operating modes of the transducers near the electric resonance frequencies were investigated, when the oscillations were excited by voltage, as well as the operating modes of the transducers near the electric antiresonance frequencies were investigated, when thevibrations were excited by an electric current applied to electrodes.

Finite element calculations showed that the porous piezoelectric ceramics has a greater effectiveness of wave excitation in the acoustic medium in comparison with dense piezoceramics. Furthermore, in the case of porous piezoceramic the transducer may be composed from only one layer, while for dense ceramic the best results are obtained in the presence of additional matching elastic layers.

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